Application of High-Resolution Frequency Measurements to Studies of Critical Phenomena in Condensed Phases of Helium

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Modern microwave technology combined with high-Q resonators can achieve frequency readout and control with a resolution up to one part in $10^{17} \sim 10^{18}$. Such high-resolution measurements are more precise than most experimental techniques, and can be applied to research areas that require state-of-the-art precision. In this work, we describe the physical concepts and evaluate the required experimental procedures of applying high-resolution frequency measurement techniques to study the static and dynamic critical properties of condensed phases of helium near phase transitions. The basic approach is to resolve the resonant frequencies of a helium-filled high-Q ($Q \sim 10^9$ at 2.2 K) superconducting microwave cavity to extremely high precision (better than one part in 10^{17}) by incorporating the high-resolution thermometry (HRT) and high-resolution pressure control. The applicability of the technique to a wide range of experiments is discussed.